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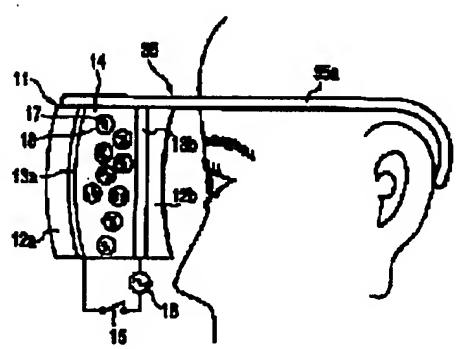
(54) **VARIABLE FOCUS SPECTACLES**

(57) Abstract

PROBLEM TO BE SOLVED: To obviate the occurrence of a boundary for a far point and for a near point and to prevent blurring when viewed at either thereof by providing part of spectacle lenses with a variable focus lens which is one of optical characteristic variable optical elements.

SOLUTION: The variable focus lens 11 comprises a first lens 12a, a second lens 12b and a high polymer dispersed liquid crystal layer 14 disposed via transparent electrodes 13a, 13b between these lenses. The transparent electrodes 13a, 13b disposed at this variable focus lens 11 are connected to an AC power source 16 via a switch 16. AC electric fields are alternately applied to the high polymer dispersed liquid crystal layer 14. The refractive index of the high polymer dispersed liquid crystal layer 14 to incident light is high and the lens having strong refracting power is obtd. in a state of not applying the electric fields thereto. As against this, the refractive index is lowered and the lens having the weak refracting power is obtd. when the alternating electric fields are applied thereto. The optical characteristics (the focal length of the lens) may be changed in such a manner and, therefore, the observation to the far point and the near point is possible when the lens is used for the spectacle lenses.



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NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] this invention relates to the adjustable focal spectacles and optical equipment which used the optical property good light variation study element and the optical property good light variation study element.

[0002]

[Description of the Prior Art] Spectacles are described for conventional optical equipment as an example.

[0003] The spectacles both for far and near the old man also enabled it to use among the conventional spectacles are composition as shown in drawing 11 . That is, as shown in drawing 11 , the lens 41 with the stage which compounded lens 41b lens 41a whose near point a focus suits, and whose far point a focus suits is used for spectacles 42.

[0004]

[Problem(s) to be Solved by the Invention] These spectacles 42 had many faults, like it fades and is visible in the state where become obstructive in case boundary 41c between two lenses 41a and 41b actually uses it, and a focus always does not suit the half of a screen.

[0005] this invention offers optical equipments, such as an optical property good light variation study element, for example, a variable-focus lens, and adjustable focal spectacles equipped with this optical property good light variation study element.

[0006]

[Means for Solving the Problem] The adjustable focal spectacles and optical equipment of this invention are adjustable focal spectacles which are characterized by having an optical property good light variation study element, and are characterized by preparing the variable-focus lens which is one of the optical property good light variation study elements at a part of spectacle lens. For example, according to these adjustable focal spectacles, a focal distance may be changed according to an observation position, without a boundary existing like the conventional example, and it looks each observation position clearly.

[0007] Moreover, this invention makes the drive unit for changing the property of an optical property good light variation study element and this optical element from another object about the creation method of optical equipment of having used the optical property good light variation study element, and is characterized by creating combining this. For example, in adjustable focal spectacles, it is the creation method of the adjustable focal spectacles characterized by creating the drive unit for changing the focal distance of a variable-focus lens and this lens with another object, and creating them combining

arbitrary frames. Moreover, the optical equipment of this invention is the thing to which it was made to change the property of the optical property good light variation study element with which detected the observation position, the measuring point, etc. and optical equipment was equipped, for example, it detects a visual axis and it is made to change the refractive power which is the optical property of a variable-focus lens in the adjustable focal spectacles of this invention.

[0008]

[Embodiments of the Invention] Drawing 1 is drawing showing the theoretic composition of the variable-focus lens of this invention. First lens 12a which has the lens sides 8a and 8b whose variable-focus lenses 11 shown in this drawing are the first page and the second page, second lens 12b which has the lens sides 9a and 9b which are the third page and the fourth page. It consists of macromolecule distribution liquid crystal layers 14 prepared through transparent electrodes 13a and 13b among these lenses, and the light which carries our incidence to this variable-focus lens is completed with the first and second lens 12a and 12b. It connects with AC power supply 16 through a switch 15, and the transparent electrodes 13a and 13b prepared in this variable-focus lens impress alternating current electric field to the macromolecule distribution liquid crystal layer 14 alternatively. In addition, the macromolecule distribution liquid crystal layer 14 is the composition of having many minute macromolecule cells 18 of the configurations where a globular shape, a polyhedron, etc. are arbitrary which contain the liquid crystal molecule 17, respectively, and the macromolecule and the liquid crystal molecule 17 which constitute the macromolecule cell 18 make it in agreement [volume/the] with the sum of the volume occupied, respectively. In addition, you may use the macromolecule stabilization liquid crystal instead of the polymer-liquid-crystal layer 14.

[0009] Here - the size of the macromolecule cell 18 - for example, supposing the configuration is spherical, when setting to lambda wavelength of the light which uses the diameter D of the average, it is made the value within the limits shown in the following formula (1):

2 nm<=D<lambda / 5 (1)

[0010] That is, since the size (average diameter) of the liquid crystal molecule 17 is about 2nm or more, the lower limit of the average diameter D is set to 2nm or more. Moreover, although a D value is dependent also on thickness t of the macromolecule distribution, liquid crystal layer 14 in the direction of an optical axis of a variable-focus lens 11. If a D value is large compared with lambda, since light will be scattered about and the macromolecule distribution liquid crystal layer 14 will become opaque in the interface of the macromolecule, and the refractive index of the liquid crystal molecule 17, as for the lower limit of a formula (1), it is desirable that it is lambda/5 or less by the reason explained later. A high precision may not be required depending on the optical product for which a variable-focus lens is used, and D should just be below lambda in that case. In addition, the transparency of the macromolecule distribution liquid crystal layer 14 becomes so bad that thickness t is thick.

[0011] Moreover, in using the macromolecule stabilization liquid crystal 414 as shown in drawing 3 instead of macromolecule distribution liquid crystal, the average diameter D of the liquid crystal shall that the average interval of the liquid crystal groups separatedf by the macromolecule 415.

[0012] Moreover, as a liquid crystal molecule 17 in drawing 1, etc., the optically uniaxial pneumatic liquid crystal molecule is used, for example. The index ellipsoid of this liquid crystal molecule 17 is a configuration as shown in drawing 5, and the following formula (2) is realized:
nox=noy=no (2)
However, the refractive index of an ordinary ray, and nox and noy are the refractive indexes of the direction of an inside including an ordinary ray which intersects perpendicularly mutually.
[0013] Here, in the variable-focus lens shown in drawing 1, wince the liquid crystal molecule 17 has turned to various directions in the state where electric field are not impressed to OFF 14, i.e., a macromolecule distribution liquid crystal layer, the refractive index of the macromolecule distribution liquid crystal layer 14 to an incident light has an expensive switch 15, and it becomes the strong lens of refractive power. On the other hand, if a switch 15 is turned ON and alternating current electric field are impressed to the macromolecule distribution liquid crystal layer 14 as shown in drawing 2, since orientation of the liquid crystal molecule 17 is carried out so that the direction of a major axis of an index ellipsoid may become the optical axis of a variable-focus lens 11, and parallel, a refractive index will become low and it will become the weak lens of refractive power.
[0014] In addition, the voltage impress to the macromolecule distribution liquid crystal layer 14 can also be changed gradually or continuously with a variable resistor 19, as shown in drawing 4. since orientation of the liquid crystal molecule 17 is carried out so that the ellipse major axis may become the optical axis of a variable-focus lens 11, and parallel gradually, it can change refractive power gradually or continuously, as applied voltage will become high, if it does in this way.
[0015] As shown in drawing 5(A) here in the state which a variable-focus lens shows to distribution liquid crystal layer 14, it is nz about the refractive index of the direction of a major axis of an index ellipsoid. If it carries out, average refractive-index nLC' of the liquid crystal molecule 17 will be given by the almost following formula (3):
(nox+noy+nz) /3=nLC' (4)
[0016] Moreover, the average refractive index nLC in case the above-mentioned formula (2) is realized is nz. Refractive index ne of an extraordinary ray. If it carries out, it will be given by the following formula (4):
(2no +ne) /3=nLC (4)
[0017] At this time, it is nP about the refractive index of the macromolecule which constitutes the macromolecule cell 18. If it carries our and the rate of the volume of the liquid crystal molecule 17 occupied for the volume of the macromolecule distribution liquid crystal layer 14 is set to ff, the refractive index of the macromolecule distribution liquid crystal layer 14 will be given by the following formula (5) by the principle of a maxwell garnet.
nA = ff-nLC'+(1-ff) nP (5)
[0018] Therefore, as shown in drawing 4, it is the radius of curvature of the field inside lens 12a and lens 12b, i.e., the field by the side of the macromolecule distribution liquid crystal layer 14, respectively R1 and R2. When it carries out, it is the focal distance f1 of a variable-focus lens 11. It is given by the following formula (6):

1/f1 =(nA -1)(1/R1 -1/R2) (6)
[0019] In addition, R1 And R2 The time of center of curvature being in an image point side is made positive. Moreover, the refraction by the field inside lens 12a and lens 12b is removed. That is, the focal distance of the lens only by the macromolecule distribution liquid crystal layer 14 is given by the formula (6).
[0020] Moreover, refractive index nB of the macromolecule distribution liquid crystal layer 14 in the state where electric field were impressed to the state 14, i.e., macromolecule distribution liquid crystal layer, shown in drawing 2 It is given by the following formula (7).
nB =ff-no '+(1-ff) nP (7)
[0021] no ' is expressed by the following formula (8) by the refractive index of an ordinary ray here.
no '= (noz+noy)/2 (8)
[0022] Therefore, the focal distance f of the lens only by the macromolecule distribution liquid crystal layer 14 in this state is given by the following formula (9).
1/f2 =(nB -1)(1/R1 -1/R2) (9)
[0023] In addition, the focal distance in the case of impressing low voltage is the focal distance f1 given by (6) formulas rather than it can set in the macromolecule distribution liquid crystal layer 14 at drawing 4 . Focal distance f2 given by (9) formulas It becomes the value of a between.
[0024] From the above-mentioned formula (6) and a formula (9), the rate of change of the focal distance by the macromolecule distribution liquid crystal layer 14 is given by the following formula (10).
|(f2 -f1)/f2 |=|(nB -nA)/(nB -1)| (10)
[0025] Therefore, what is necessary is just to enlarge |nB-nA |, in order to enlarge this rate of change. this (nB-nA) -- it is expressed with the following formula
nB-nA =ff (no '-nLC') (11)
[0026] Therefore, if |no '-nLC| is enlarged, rate of change can be enlarged. It is nB practical. Since it is 1.3 to about two 0.01 <=|no '-nLC'|<=10 (12)
Then, since the focal distance by the macromolecule distribution liquid crystal layer 14 is changeable 0.5% or more at the time of ff=0.5, an effective variable-focus lens can be obtained. In addition, |no '-nLC'| cannot exceed 10 from a limit of the liquid crystal matter.
[0027] Next, the basis of the upper limit of the above-mentioned (1) formula is explained.
[0028] "Solar Energy Msterials and Solar Cells" Change of the permeability tau when changing the size of macromolecule distribution liquid crystal is shown in the 197-214th page of 31 volumes, Wilson and Eck, 1993, and Eleevier Science Publishers B.V. issue, and "Transmission variation using scattering/transparent switching films." and in the 206th page of the above-mentioned reference, and a view 6 When the radius of macromolecule distribution liquid crystal is set to r and it is referred to as t= 300 micrometers, ff=0.5, nP =1.45, nLC=1.585, and lambda= 500nm, permeability tau With the theoretical value, it becomes tau**90% at the time of r= 5nm (D=lambda/50, D-t=lambda, 6 micrometers (however, the same of the unit of D and lambda is said of nm and the following)), and the bird clapper is shown to tau**50% at the time of r= 25nm (D=lambda/10).
[0029] Here, if permeability tau will assume that it changes by the exponential function

of t if the case of t= 150 micrometers is presumed, and the permeability tau in t= 150 micrometers is presumed, it will become tau**71% at the time of r= 25nm (D=lambda/10, D-t=lambda, 15 micrometers). Moreover, in the case of t= 75 micrometers, it becomes tau**80% similarly at the time of r= 25nm (D=lambda/10, D-t=lambda, 7.5 micrometers).

[0030] If these results to D-t is within the limits shown by the following formula (13), tau will become 70% - 80% or more, and will be used enough as a lens. It follows, for example, in the case of t= 75 micrometers, it is D<=lambda/5, and sufficient permeability will be obtained.

D-t<=lambda, 15 micrometers (13)

[0031] Moreover, the permeability of the macromolecule distribution liquid crystal layer 14 is nP. It becomes so good that a value is close to the value of nLC'. On the other hand, they are no ' and nP. If it becomes a different value, the permeability of the macromolecule distribution liquid crystal layer 14 will become bad. It is with the state of <u>drawing 1</u> , and the state of <u>drawing 2</u> , and it is a time of satisfying the following formula (14) that the permeability of the macromolecule distribution liquid crystal layer 14 becomes good on the average.

nP = (no '+nLC')/2 (14)

[0032] Here, since a variable-focus lens 11 is used as a lens, its higher one where permeability is almost the same is good also in the state of the state of <u>drawing 1</u> , or <u>drawing 2</u> . For that purpose, although the material of the macromolecule which constitutes the macromolecule cell 18, and the material of the liquid crystal molecule 17 have a limit, it is a refractive index nP practical. A value should just satisfy the following formula (15).

no '<=nP <=nLC' (15)

[0033] If the above-mentioned formula (14) is satisfied, the above-mentioned formula (13) is eased further and the value of D-t should just be a range shown in the following formula (16).

D-t<=lambda, 60 micrometers (16)

[0034] Since a reflection factor is proportional to the square of a refractive-index difference according to the reflective rule of full flannel, reflection of the light in the boundary of the macromolecule and the liquid crystal molecule 17 which constitute the macromolecule cell 18, i.e., reduction of the permeability of the macromolecule distribution liquid crystal layer 14, is because it is proportional to the square of the difference of the refractive index of the above-mentioned macromolecule and the liquid crystal molecule 17 about.

[0035] Although the above was the case of no '**1.45 and nLC'**1.585, when it more generally formulizes, D-t should just be within the limits of the following formula (17).

D-t<=lambda, 15 micrometers (1.585-1.45), 2/(nu-nP) 2 (17)

However, 2 (nu-nP) (nLC'-nP) and 2 (no '-nP) They are inside and the larger one.

[0036] Moreover, in ff=1, although the one where the value of ff is larger is good in order to enlarge focal distance change of a variable-focus lens 11, since the volume of a macromolecule serves as zero and it becomes impossible to form the macromolecule cell 18, the value of ff is the range of the following formula (18).

0.1 <=ff<=0.999 (18)

[0037] Since tau improves so that ff is small, the value of D-t has [the above-mentioned

formula (17)] the range desirable [on the other hand,] of the following formula (19) preferably.

4x10-6[mum] 2 <= D-t<=lambda, 45 micrometers (1.585-1.45), 2/(nu-nP) 2 (19)

[0038] In addition, since it is t=D and D is 2nm or more as mentioned above so that clearly [the lower limit of t] from drawing 1 , the lower limit of D-t is 2 (2x10 to 3 micrometer), 4x10-6 [i.e.,]. 2 It becomes.

[0039] The above was the case where dispersion of the light by the variable-focus lens and permeability required a quite good value. However, it may be necessary to improve permeability dispersion so much, and in the optical system of a low cost, image pck-up equipment, an illumination system, a signal-processing system, etc., a formula (19) is eased, as further shown in the following formula (19-5).

4x10-6[mum] 2 <= D-t<=lambda, 450 micrometers (1.585-1.45), 2/(nu-nP) 2 (19-5)

[0040] In addition, D is a larger case than 10nm - 5nm as it is indicated by the 58th page of Mukai ["whom an Iwanami science library 8 asteroid comes"] right work, 1994, and the Iwanami Shoten issue that the approximation which expresses the optical property of the matter with a refractive index is realized. Moreover, if D exceeds 500lambda, since dispersion of the light in the interface of the macromolecule and the liquid crystal molecule 17 which dispersion of light becomes geometric and constitute the macromolecule cell 18 will increase according to Fresnel's reflective formula, D is within the limits of the following formula (20) practical.

7nm<=D<=500lambda (20)

[0041] the composition shown in drawing 1 or drawing 3 -- setting -- above nox, noy and no, nz, ne, nP, ff, D, t, lambda and R1, R2, nLC', nA, nB, f1, and f2 And specifically, the diameters phi of a variable-focus lens 11 are the following values, respectively.

[0042] 2 = 48.04mm [of nox=noy=no =1.5nz =ne =1.75np =1.54ff=0.5D=50nmt=125micrometerlambda=500nmR1 =25mmR2 =infinitynLC'=nLC=1.5833nA =1.5617nB =1.52f1 =44.5mmf(s)] phi= 5mm [0043] In this case, the right-hand side of the above-mentioned formula (19) is as follows.

2/(nu-nP) lambda-45-micrometer 2= 500nm and, 45-micrometer, and (0.135) 2-/(0.0433) 2**218712nm-mum [0044] Moreover, D-t is as follows and satisfies a formula (19).

D-t=50nmand125micrometer=6250nm-mum [0045] Moreover, in the above-mentioned example, it can also consider as R1 =R2 =infinity. In this case, since the optical path length of the macromolecule distribution liquid crystal layer 14 will change by turning on and off of voltage, it can use for the flux of light of a lens system arranging a variable-focus lens 11 into the portion which is not parallel, and performing focus adjustment, or can use for changing the focal distance of the whole lens system etc.

[0046] As an example of the liquid crystal matter which can be used as a liquid crystal molecule 17 in order to make macromolecule distribution liquid crystal or macromolecule distribution liquid crystal, there is smectic-liquid-crystal, chiral cholesteric-liquid-crystal, cholesteric-liquid-crystal, smectic-liquid-crystal, smectic C* liquid crystal, ferroelectric liquid crystal, antiferroelectric-crystal liquid crystal, tolan system liquid crystal, difluoro stilbene system low viscosity compound, and banana type liquid crystal etc. other than a nematic liquid crystal, and the optical property good light variation study element of this invention can be realized using such liquid crystal.

[0047] Drawing 6 shows the composition of the image pck-up optical system for digital cameras which is one of the image pck-up equipment using the variable-focus lens 11

shown in drawing 4 . In this image pck-up optical system, image formation of the objective (not shown) image is carried out through drawing 21, a variable-focus lens 11, and a lens 22 on the solid state image pickup device 23 which consists of CCD. In addition, illustration of a liquid crystal molecule is omitted in drawing 6 .

[0048] It is possible to make it focus continuously to the object distance from infinite distance to 600mm for example, without moving a variable-focus lens 11 and a lens 22 in the direction of an optical axis by adjusting the alternating voltage impressed to the macromolecule distribution liquid crystal layer 14 of a variable-focus lens 11 with a variable resistor 19, and changing the focal distance of a variable-focus lens 11 according to such image pck-up optical system.

[0049] Drawing 7 shows the composition of the object optical system for electronic endoscopes which used the variable-focus lens of this invention. This object optical system carries out image formation of the objective (not shown) image for example, on the solid state image pickup device 29 which consists of CCD with the front lens 25, drawing 26, a variable-focus lens 27, and the back lens 28. It is the same composition as drawing 5 , and alternating voltage is made to be impressed here except having made the radius of curvature R1 of the inside of lens 12a into infinity (flat surface), and while pinching the macromolecule distribution liquid crystal layer 14 of a variable-focus lens 27 having made the inside of lens 12b of another side the shape of a Fresnel lens from AC power supply 16 through a variable resistor 19 and a switch 15 to the macromolecule distribution liquid crystal layer 14. In addition, drawing 7 has omitted illustration of a liquid crystal molecule.

[0050] Also in such object optical system, it is possible to perform focus adjustment, without changing the focal distance of a variable-focus lens 27, and moving a variable-focus lens 27 and the back lens 28 in the direction of an optical axis by adjusting the alternating voltage impressed to the macromolecule distribution liquid crystal layer 14 of a variable-focus lens 27 according to the object distance.

[0051] Drawing 8 is one of the optical property good light variation study elements of this invention, and shows an example of the adjustable focal diffraction optical element used for optical equipments, such as image pck-up equipment and adjustable focal glasses.

[0052] The 1st transparent substrate 32 which has 1st page 32a and 2nd page 32b of a flat surface with the parallel adjustable focal diffraction optical element 31 shown in this drawing, It has the 2nd transparent substrate 33 which has 3rd page 33a and flat 4th page 33b in which the ring-like diffraction grating of the cross-section serration sinuate which has the depth of flute of the wavelength order of light was formed, and outgoing radiation of the incident light is carried out through the 1st and 2nd transparent substrate 32 and 33. Between the 1st and 2nd transparent substrate 32 and 33, the macromolecule distribution liquid crystal layer 14 is similarly formed through transparent electrodes 13a and 13b with drawing 1 having explained, transparent electrodes 13a and 13b are connected to AC power supply 16 through a switch 15, and it may have comes to impress alternating current electric field to the macromolecule distribution liquid crystal layer 14.

[0053] If the beam of light which carries out incidence to the adjustable focal diffraction optical element 31 of such composition sets the lattice pitch of 3rd page 33a to p and m is made into an integer, it will deflect and carry out outgoing radiation only of the angle theta shown in the following formula (21).

p sintheta=mlambda (21)

[0054] Moreover, if the refractive index of h and the transparent substrate 33 is set to n33 for the depth of flute, k is made into an integer and the following formula (22) and (23) will be satisfied, diffraction efficiency becomes 100% on wavelength lambda, and generating of the flare can be prevented:

h (nA-n33) = mlambda (22)

h (nB-n33) = klambda (23)

[0055] Here, if the difference of both sides of the above (22) and (23) formulas is searched for the following formula (24) will be obtained:

h (nA-nB) = (m-k) lambda (24)

[0056] It is as follows when [follow, for example] lambda = 500nm, nA = 1.55, and nB = 1.5.

0.05h= (m-k), 500nm

[0057] The value of h is as follows when [here] m= 1 and k= 0.

h= 10000nm = 10 micrometers

[0058] In this case, the refractive index n33 of the transparent substrate 33 should just be n33-1.5 from the above-mentioned formula (22). Moreover, if lattice-pitch p in the periphery of the adjustable focal diffraction optical element 31 is set to 10 micrometers, it becomes theta**2.87 degrees and the f number can obtain the lens of 10.

[0059] Since such an adjustable focal diffraction optical element 31 changes the optical path length by turning on and off of the applied voltage to the macromolecule distribution liquid crystal layer 14, it can be used for the flux of light of a lens system arranging for example, into the portion which is not parallel, and performing focus adjustment, or can be used for changing the focal distance of the whole lens system, etc.

[0060] In addition, what is necessary is just to satisfy the following formula (25), (26), and (27) instead of the above-mentioned formula (22, (23), and (24) practically in the form of this operation, respectively:

0.7MLambda<=h(NA-N33) <=1.4MLambda (25)

0.7KLambda<=h(NB-N33) <=1.4KLambda (26)

0.7(m-k) lambda<=(nA-nB) <1.4(m-k) lambda (27)

[0061] Drawing 9 and drawing 10 show the adjustable focal glasses which used the variable focus lens 11 as a spectacle lens.

[0062] Since the adjustable focal glasses 37 shown in these views can change the array of the liquid crystal molecule 17 of the macromolecule distribution liquid crystal layer 14 in the time of turning ON a switch 15 as shown in drawing 9 and drawing 10, respectively, when a switch 15 is turned OFF by turning Switch 15 on and off manually, they can change the diopter of the whole spectacle lens. Therefore, compared with the glasses which change a diopter, sense of incongruity is lost in the direction of a look like the glasses 42 using the conventional double focal lens 41 shown in drawing 11.

[0063] Moreover, the adjustable focal glasses shown in drawing 12 had formed the ranging sensor 46 which measures the distance to a body 45 in frame 35a in the adjustable focal glasses 35 shown in drawing 9, control turning on and off of a switch 15 based on the output of this ranging sensor, and enabled it to adjust the diopter of a spectacle lens automatically.

[0064] Thus, since diopter adjustment can be automatically performed according to the object distance, glasses convenient for the old man in whom especially the diopter adjustment force declined are obtained.

[0065] In addition, although the adjustable focal glasses 35 shown in drawing 12 made the whole spectacle lens the variable-focus lens 11, you may make it form a variable-focus lens 11 in a nose twist with the bottom or the down side a little from a center, as shown, the part, for example, drawing 13 , of a spectacle lens.
[0066] Moreover, since a level difference with the portion with as other making into the configuration of a convex lens the portion of the variable-focus lens 11 prepared in a part of spectacle lens as the portion of this variable-focus lens 11 can be made small as shown in drawing 13 , in case it sees through glasses, it is [seldom] interfered and is desirable [a level difference]. In addition, in 13 view, (A) is a perspective diagram and (B) is a cross section.
[0067] Furthermore, in the above-mentioned adjustable focal spectacles 35, AC power supply 16 can be constituted with the oscillator circuit or inverter circuit which uses a cell as a power supply. In this case, as a cell,-like, it builds or a kind of a manganese cell, a lithium cell 409, a solar battery 410, and a rechargeable battery 411 or two or more sorts are really prepared in or more 1 frame 35a at another object, and connect in code, or it prepares in a lens front face, or can have a built-in cell and an external cell.
[0068] Moreover, when it constitutes adjustable focal spectacles, it can replace with the variable-focus lens using above-mentioned macromolecule distribution liquid crystal, and the variable-focus lens using the twist pneumatic liquid crystal which is the gestalt of the 2nd operation can also be used. Drawing 14 and drawing 15 are what shows the composition of the adjustable focal spectacles 50 in this case. a variable-focus lens 51 Lenses 52 and 53 and the orientation films 39a and 39b prepared through transparent electrodes 13a and 13b, respectively on the inside of these lenses, The twist pneumatic liquid crystal layer 54 prepared between these orientation films is had and constituted, the transparent electrodes 13a and 13b are connected to AC power supply 16 through a variable resistor 19, and it is made to have impressed alternating current electric field to the twist pneumatic liquid crystal layer 54.
[0069] In the adjustable spectacle lens of such composition, if voltage impressed to the twist pneumatic liquid crystal layer 54 is made high, the liquid crystal molecule 55 serves as a homeotropic orientation, as shown in drawing 15 , compared with the case where the applied voltage shown in drawing 14 is in a low twist pneumatic state, the refractive index of the twist pneumatic liquid crystal layer 54 will become small, and a focal distance will become long. If a variable resistor 19 is adjusted here, a focal distance may be changed continuously.
[0070] Here, since the wavelength lambda of light is small to dozens or less times and it is necessary to carry out the spiral pitch P of the liquid crystal molecule 55 in the twist pneumatic state shown in drawing 14 , as for Pitch P, it is desirable to satisfy the following formula (28), for example.
2nm<=P<=60lambda (28)
[0071] In addition, the lower limit of this condition is decided by liquid crystal molecular size, and it is the value which needs a upper limit in order that the twist pneumatic liquid crystal layer 54 may act as an isotropic medium in the state of drawing 14 when an incident light is the natural light, and if the conditions of this upper limit are not satisfied, only the image which the variable-focus lens 51 turned into a lens from which a focal distance differs by the polarization direction, therefore the double image was formed, and faded will be obtained.

[0072] Next, the conditions for the liquid crystal layer 54 acting as an isotropic medium to an incident light optically are explained.
[0073] If the pitch P of the deflection of a pneumatic liquid crystal 54 (P shown in drawing 14) is very small compared with the wavelength lambda of light temporarily now, this variable-focus lens will not be based on the state of polarization of an incident light, but will act as a medium of refractive-index n'. That is, it is as the following formula (5-1).
P<<lambda (5-1)
[0074] Thus, if Pitch P is very small compared with the wavelength lambda of light, this variable-focus lens will not be based on polarization of an incident light, but will act as a medium with refractive-index n' given below (5-2).
n'=(ne+no)/2 (5-2)
[0075] Here, a refractive index [as opposed to polarization of the direction of a liquid crystal molecule major axis in ne] and no are the refractive indexes to polarization of the direction of a ****** minor axis. The index ellipsoid corresponding to the liquid crystal molecule by the side of the incidence of a pneumatic liquid crystal 54 is shown in drawing 5 (B). Here, a x axis and the z-axis have become in the direction of a minor axis of a liquid crystal molecule, and the y-axis has become in the direction of a major axis of a liquid crystal molecule. In addition, it considers as ne>no. [0076] Next, vector and matrix of Jones explain why the NEMATTEKU liquid crystal of the gestalt of this operation acts as an isotropic medium of refractive-index n' in execution.
[0077] According to the formula 3-10, the formula 3-110, and formula 3-126 which are shown in 85 pages - 92 pages of Katsumi Yoshino of the Corona Publishing Co., Ltd. issue, and Masanori Ozaki collaboration "the foundation of liquid crystal and display application", when the change exp (-ialpha) of an absolute phase is included, Jones's matrix Wt over the NEMATEKKU liquid crystal of thickness d shown in drawing 14 is given by the following formula (5-3).

$$W_t = e^{-i\alpha} R(-\Phi) \begin{bmatrix} \cos X - i\frac{\Gamma}{2}\frac{\sin X}{X} & \Phi\frac{\sin X}{X} \\ -\Phi\frac{\sin X}{X} & \cos X + i\frac{\Gamma}{2}\frac{\sin X}{X} \end{bmatrix} \quad (5-3)$$

[0078] However, phi, gamma, alpha, X, and R (-phi) are the passages of the following formula (5-4), (5-5), (5-6), (5-7), and (5-8), respectively.
phi=2pid/P (5-4)

$$\Gamma = 2\pi\,(n_e - n_o)\,\frac{d}{\lambda} \quad (5-5)$$

$$\alpha = 2\pi\,\frac{(n_e+n_o)}{2}\,\frac{d}{\lambda} \quad (5-6)$$

$$X = \sqrt{\Phi^2 + \frac{\Gamma^2}{2}} \quad (5-7)$$

$$R(-\Phi) = \begin{bmatrix} \cos\Phi & -\sin\Phi \\ \sin\Phi & \cos\Phi \end{bmatrix} \quad (5-8)$$

[0079] When Tsunemitsu is defined as polarization of the direction of a minor axis of a liquid crystal molecule here and it is defined as polarization of the direction of [when

projecting unusual light to polarization of the direction of a major axis of a liquid crystal molecule, and projecting a major axis to a flat surface perpendicular to an optical axis], gamma expresses the phase contrast of Tsunemitsu by NEMATEKKU liquid crystal, and unusual light.

[0080] In addition, phi expresses the twist angle of the liquid crystal molecule of the NEMATEKKU liquid crystal 54 with a radian. The system of coordinates of **** (5-3) and a formula (5-8) shall be taken like x and y which are shown in drawing 5 (B), and the z-axis. That is, the x axis is going to the front shell background of space, and the y-axis is the direction of the liquid crystal molecule major axis in the plane of incidence of chiral NEMATEKKU liquid crystal. Under the conditions of a formula (5-1), it investigates what Wt of a formula (5-3) becomes.

[0081] A formula (5-1) can deform like the following formula (5-9).

0< P/lambda <<1 (5-9)

[0082] Then, p/lambda -> the limit value WtL of Wt of a formula (5-3) is calculated at the time of 0.

[0083] Gamma/phi is given by (5-10).

Gamma/phi= (ne-no) (P/lambda) (5-10)

[0084] Therefore, gamma/phi comes to be shown in a formula (5-11) at the time of P/lambda <<1.

I Gamma/phi I<<1 (5-11)

[0085] Therefore, P/lambda -> it is set to I gamma/phi I->0 at the time of 0.

[0086] Under the conditions of a formula (5-11), X of a formula (5-7) becomes as shown in the following formula (5-12), (5-13), and (5-14).

$$X = \Phi \sqrt{(1+\frac{\Gamma^2}{2\Phi^2})} \fallingdotseq \Phi + \frac{\Gamma^2}{4\Phi} \qquad (5-12)$$

$$\cos X \fallingdotseq \cos\ (\Phi + \frac{\Gamma^2}{4\Phi}) \qquad (5-13)$$

$$\frac{\Gamma}{2}\frac{\sin X}{X} \fallingdotseq \frac{\Gamma}{2}\frac{\sin(\Phi+\frac{\Gamma^2}{4\Phi})}{\Phi+\frac{\Gamma^2}{4\Phi}} \qquad (5-14)$$

$$\Phi\frac{\sin X}{X} \fallingdotseq \frac{\sin(\Phi+\frac{\Gamma^2}{4\Phi})}{1+\frac{\Gamma^2}{4\Phi^2}} \qquad (5-15)$$

It can approximate and is each at the time of P/lambda ->0. X->phi (5-16)

cosX->cosphi (5-17)

$$\frac{\Gamma}{2}\frac{\sin X}{X} \to 0 \qquad (5-18)$$

$$\Phi\frac{\sin X}{X} \to \sin\Phi \qquad (5-19)$$

Since it becomes, WtL becomes as shown in (5-20) at the time of P/lambda ->0.

$$W_{tL} \to e^{-i\alpha} R\ (-\Phi) \begin{bmatrix} \cos\Phi & \sin\Phi \\ -\sin\Phi & \cos\Phi \end{bmatrix} = e^{-i\alpha} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \qquad (5-20)$$

[0087] this -- the optical axis of refractive-index n'= (ne+no)/2 and thickness d -- meeting -- etc. -- it is exactly the Jones matrix of a **** medium

[0088] Therefore, since it is P/lambda <<1, the variable-focus lens 21 of drawing 12 can realize image formation which acts as a lens of refractive-index n' and does not have dotage.

[0089] In addition, it is able to make it to be satisfied [with replacing the value of ne by rate neof unusual optical refraction' which is a middle value with ne and no, when liquid crystal is a middle array like drawing 16] of above-mentioned formula (5-3) - (5-20).

[0090] In addition, even if it does not restrict strangely [possible / continuation] as the method of impression of voltage but chooses applied voltage from some dispersed voltage values, a variable-focus lens is realizable.

[0091] Here, the practical example of the variable-focus lens of composition like drawing 14 is explained in detail.

[0092] Although the case of the limit of P/lambda ->0 is shown in the formula (5-20), since limit value may not necessarily be applied for disorder of liquid crystal molecular arrangement etc., the approximation of a formula (5-3) is drawn by the actual liquid crystal lens and the variable-focus lens. You may not be P/lambda <1 and, also in P/lambda >=1, it is contained.

[0093] When even the 1st order of P/lambda is considered and a formula (5-3) is approximated, it is as follows about it. That is, if it leaves even the 1st order of gamma/phi and the 2nd more than order of gamma/phi is omitted from to (5-10) the 1st order of P/lambda, i.e., a formula, by the formula (5-12) - the formula (5-14), it will become like a formula (5-21).

$$\cos X - i\frac{\Gamma}{2}\frac{\sin X}{X} \fallingdotseq \cos\left(\Phi + \frac{\Gamma}{4}\frac{\Gamma}{\Phi}\right) - i\frac{\Gamma}{2\Phi}\sin\left(\Phi+\frac{\Gamma}{4}\frac{\Gamma}{\Phi}\right) \qquad (5-21)$$

$$\Phi\frac{\sin X}{X} \fallingdotseq \sin\left(\Phi+\frac{\Gamma}{4}\frac{\Gamma}{\Phi}\right) \qquad (5-22)$$

[0094] The following formula (5-23) is obtained from these formulas (5-20), (5-21), and (5-22).

$$W_t \fallingdotseq e^{-i\alpha} R\,(-\Phi) \begin{bmatrix} \cos(\Phi+\frac{\Gamma}{4}\frac{\Gamma}{\Phi}) - i\frac{\Gamma}{2\Phi}\sin(\Phi+\frac{\Gamma}{4}\frac{\Gamma}{\Phi}) & \sin(\Phi+\frac{\Gamma}{4}\frac{\Gamma}{\Phi}) \\ -\sin(\Phi+\frac{\Gamma}{4}\frac{\Gamma}{\Phi}) & \cos(\Phi+\frac{\Gamma}{4}\frac{\Gamma}{\Phi}) + i\frac{\Gamma}{2\Phi}\sin(\Phi+\frac{\Gamma}{4}\frac{\Gamma}{\Phi}) \end{bmatrix}$$

$$\equiv W_{tN} \qquad (5-23)$$

[0095] Therefore, in order to be able to consider that the value of WtN is almost equal to the Jones matrix of an isotropic medium, | i-gamma / 2phi| should be just close to 0. At this time, WtN approaches the following formula (5-24).

$$e^{-i\alpha}\begin{bmatrix} \cos(\frac{\Gamma}{4}\frac{\Gamma}{\Phi}) & \sin(\frac{\Gamma}{4}\frac{\Gamma}{\Phi}) \\ -\sin(\frac{\Gamma}{4}\frac{\Gamma}{\Phi}) & \cos(\frac{\Gamma}{4}\frac{\Gamma}{\Phi}) \end{bmatrix} \qquad (5-24)$$

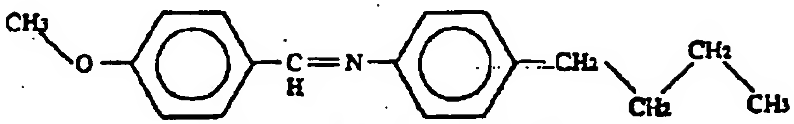
[0096] This formula (5-24) means that it can be considered that it is an isotropic medium, although liquid crystal rotates only polarization direction gamma / 4, and gamma/phi of

an incident light.
[0097] Therefore, if it is got blocked and a formula (5-26) is satisfied about, the variable-focus lens for which the following formula (5-25) is satisfied and not fading will be obtained.
| i and (gamma/2phi) |**0 (5-25)
| gamma/2phi|<<1 (5-26)
[0098] gamma/2phi is expressed with the following formula (5-27) from a formula (5-10).
gamma/2phi= (P/lambda) (1/2) (ne-no) (5-27)
[0099] When [of actual image pck-up equipment with a lens, for example, an electronic camera, a VTR camera an electronic endoscope, etc.] using the variable-focus lens of this invention for lenses, such as a product of a low cost, comparatively, there are few pixels of a solid state image pickup device, and since high resolving may not be required, a formula (5-26) can loosen conditions and should just satisfy the following conditions (5-28).
| gamma/2phi|<1 (5-28)
[0100] It is desirable that it is satisfied [with lenses, such as high-definition products, such as a lens of electronic image pck-up equipment with many pixels, a film camera, and a microscope,] of the following conditions (5-29) since high resolving is required.
| 2phi|<pi [gamma/]/6 (5-29)
[0101] In the case of electronic image pck-up equipment with few the lenses or the numbers of pixels which are not used for image formation, such as a lens of an optical disk, etc., conditions can be loosened further and should just satisfy the following conditions (5-30).
| gamma/2phi|<pi (5-30)
[0102] In addition, to an optical axis, although it is being able to say in common with the gestalt of this operation, when liquid crystal is a spiral array, the direction of a major axis of a liquid crystal molecule should just replace ne of a formula (5-1), a formula (5-26) - a formula (5-30) by above-mentioned ne', when not perpendicular (i.e., when slanting).
[0103] Next, the example of a design is described. This example of a design can be used also for other optical system also for spectacles.
[0104] Since the power of a lens will not be weakly helpful if thin, light will be scattered about if thick, and thickness d of NEMATEKKU liquid crystal causes the flare, as for thickness d, it is desirable to satisfy the following conditions (5-31).
2 micro<d <300micro (5-31)
[0105] Moreover, considering the light, the wavelength lambda of light is the range of the following conditions (5-32).
0.35 micro<lambda <0.7micro (5-32)
[0106] Moreover, the value of ne-no is decided by the physical properties of liquid crystal, and has much matter of the following (5-33) range.
0.01<|ne-no|<1.0 (5-33)
[0107] Moreover, especially as liquid crystal used for an optical element, the value of |ne-no| is still more useful from that the thing of the following formula (5-33-2) within the limits is chemically stable, having an optical effect, etc.
0.1<|ne-no|<0.7 (5-33-2
[0108] next -- as the example of a design -- the 1- the 4th example of a design is shown

(1st example of a design)
d=15microlambda=0.5microne-no=0.2P=0.05microphi=20mm (effective diameter of a variable-focus lens)
Then, it is set to gamma/2phi=1 / 2-0.2x0.05 / 0.5= 0.01, and a formula (5-26), a formula (5-28), a formula (5-29), and a formula (5-30) are filled.
[0109] (2nd example of a design)
It is set to d=30microlambda=0.6microne-no=0.25P=1.1microphi=50mm then gamma/2phi=1 / 2-1.1x0.25 / 0.6= 0.2292, and a formula (5-28), a formula (5-29), and a formula (5-30) are filled.
[0110] (3rd example of a design)
It is set to d=50microlambda=0.55microne-no=0.2P=5microphi=10mm then gamma/2phi=1 / 2-0.1x5.0 / 0.55= 0.909, and a formula (5-28) and a formula (5-30) are filled.
[0111] (4th example of a design)
It is set to d=200microlambda=0.95microne-no=0.2P=4microphi=2000micro then gamma/2phi=1 / 2-0.2x4 / 0.95= 0.42, and a formula (5-26), a formula (5-28), a formula (5-29), and a formula (5-30) are filled.
[0112] The 4th example of a design is examples, such as a variable-focus lens for near-infrared light.
[0113] Although each above example of a design explained taking the case of the pneumatic liquid crystal, in order to make the pitch of the spiral of a pneumatic liquid crystal small, if a chiral agent is made to liquid crystal 1% or more, for example, to mix 5% or more is good.
[0114] As a chiral agent, cholesteric liquid crystal or the optical-activity compound of synthetic compounds is used. A chemical formula (3) and a chemical formula (4) are the examples of a chiral agent about the example of a nematic liquid crystal at the following

chemical formula (1) and a chemical formula (2).

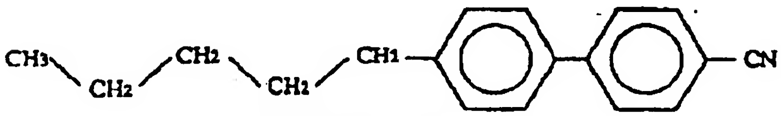
化学式 (1)



N-(4-methoxybenzylidene)-4'-n-butylaniline

(MBBA)

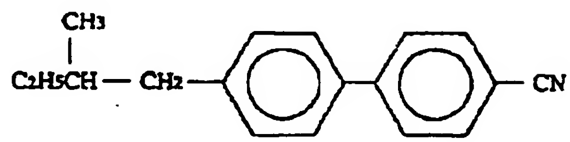
化学式 (2)



4-cyano-4'-n-pentylbiphenyl

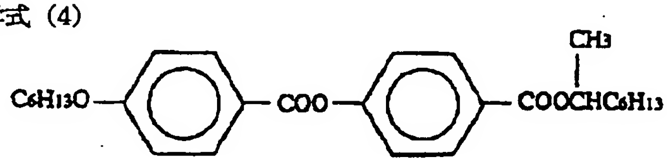
(CB − 5)

化学式 (3)



(CB − 15)

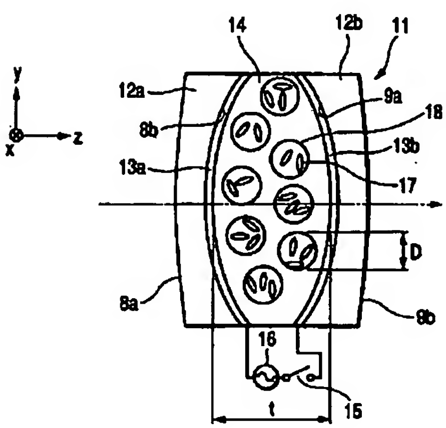
化学式 (4)



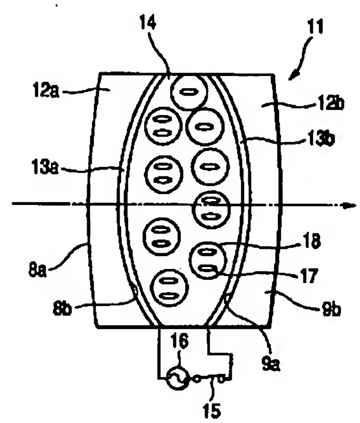
(S811)

【図３６】別体の補聴器を備えた本発明の可変焦点眼鏡
【図３７】ＰＤＡを備えた本発明の可変焦点眼鏡
【図３８】レンズ面に小型ディスプレイを設けた本発明の可変焦点眼鏡
【図３９】分割電極を設けた本発明の可変焦点眼鏡
【図４０】レンズ面にマトリックス状分割電極を設けた本発明の可変焦点眼鏡
【図４１】レンズ面に放射状分割電極を設けた本発明の可変焦点眼鏡
【図４２】ヒステリシス特性をもつ液晶を用いた本発明の可変焦点レンズ
【図４３】ヒステリシス特性をもつ液晶の電圧の変化に対する屈折率の変化を示すグラフ
【図４４】ヒステリシス特性をもつ液晶の時間に対する電圧の変化を示すグラフ
【図４５】本発明の可変偏角プリズムの構成を示す図
【図４６】本発明の他の可変偏角プリズムの構成を示す図
【図４７】本発明の可変焦点ミラーの構成を示す図
【図４８】本発明の光学装置の１例としてのデジタルカメラの構成を示す図

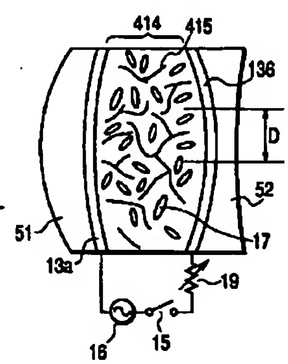
【図１】



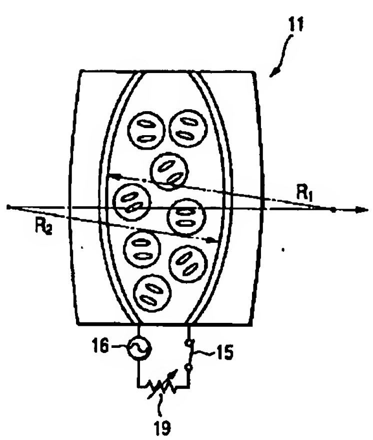
【図２】



【図３】



【図４】



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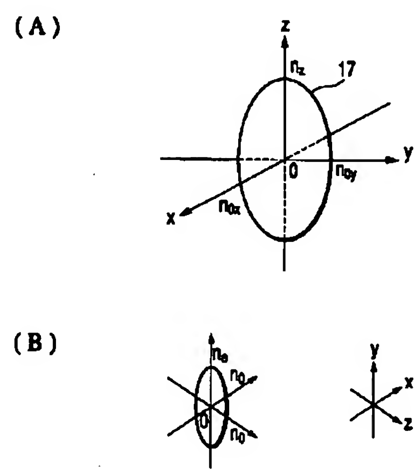
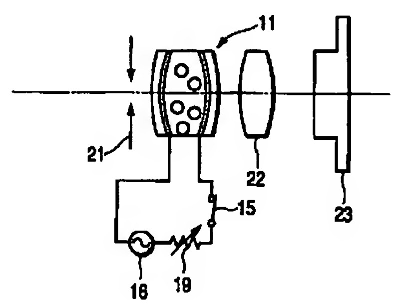
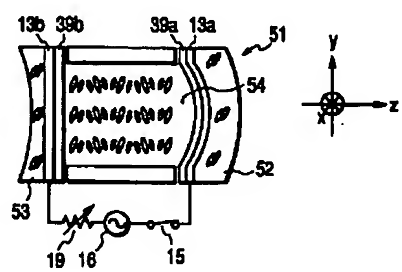


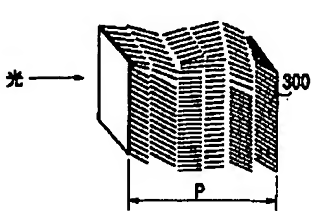
【図６】



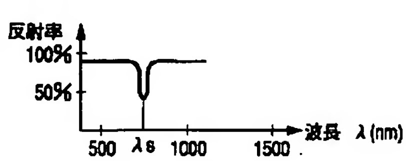
【図１６】



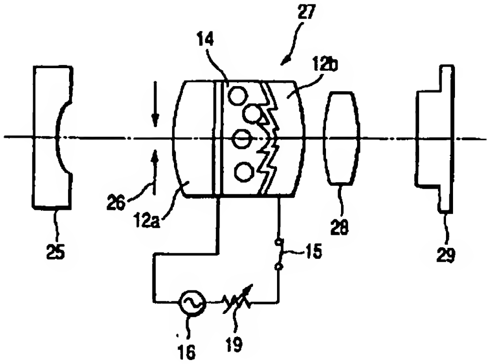
【図１７】



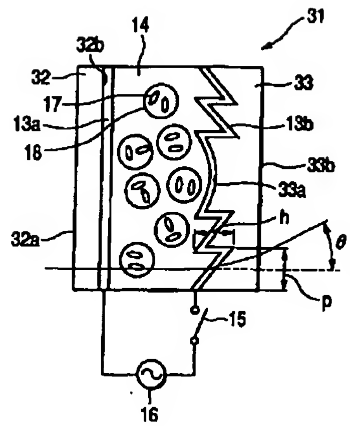
【図２０】



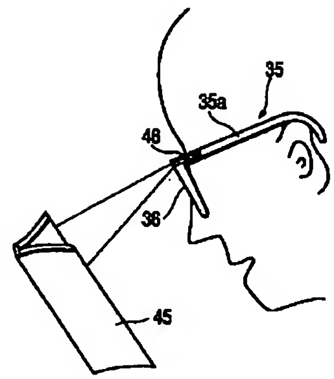
【図7】



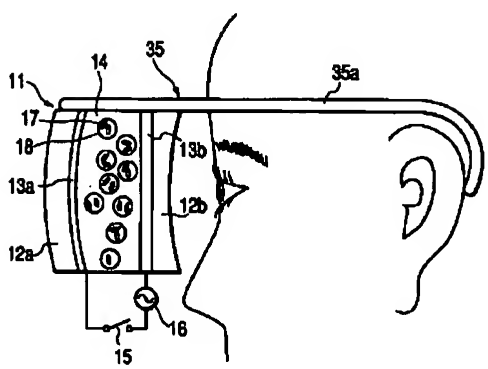
【図8】



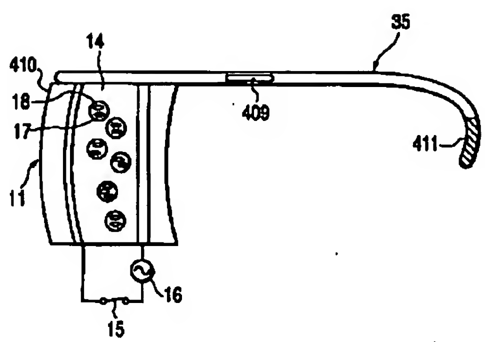
【図１２】



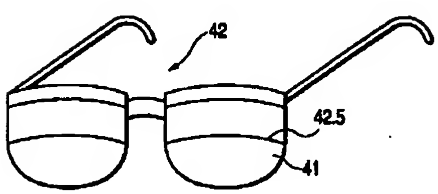
【図9】



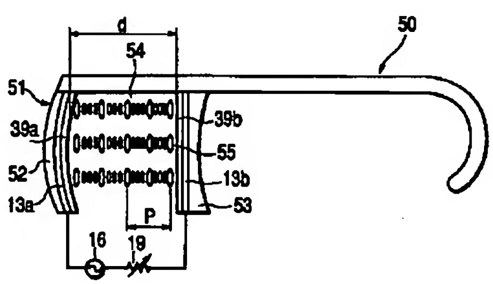
【図１０】



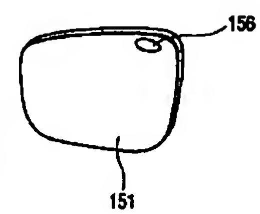
【図１１】



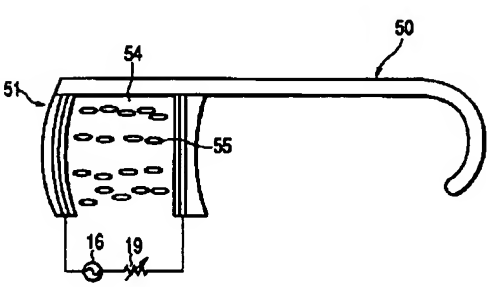
【図１４】



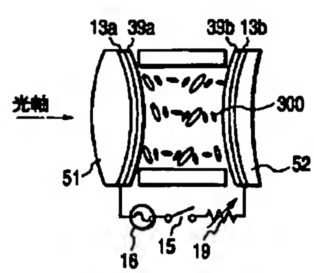
【図２８】



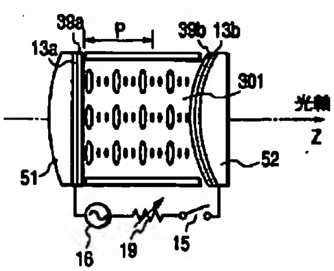
【図１５】



【図１８】



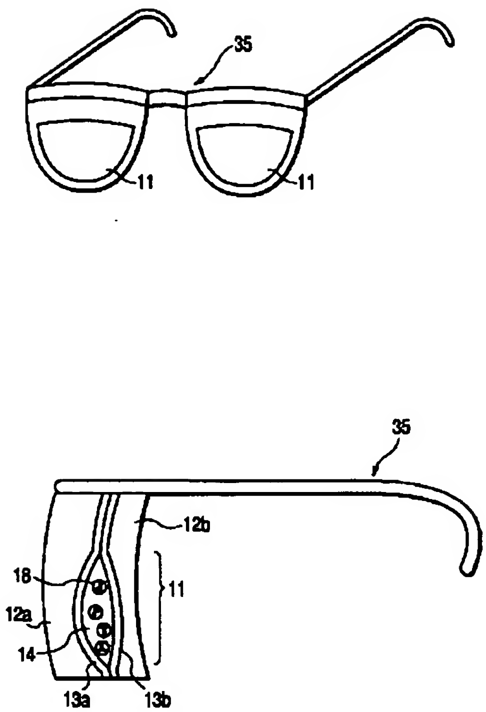
【図１９】



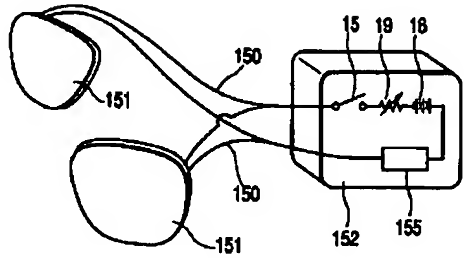
【図13】

(A)

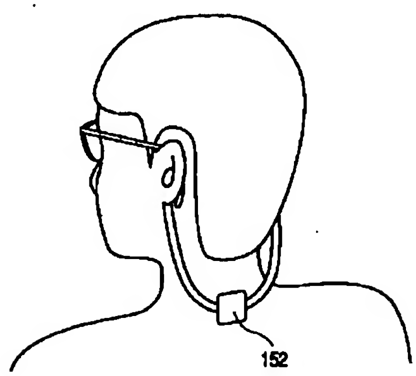
(B)



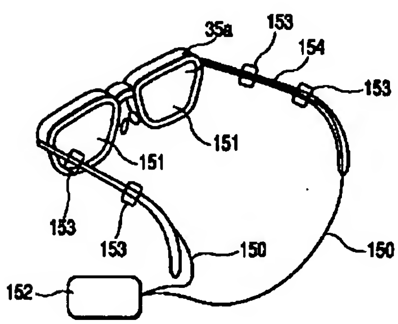
【図21】



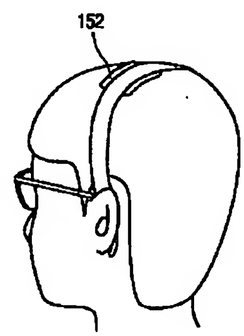
【図24】



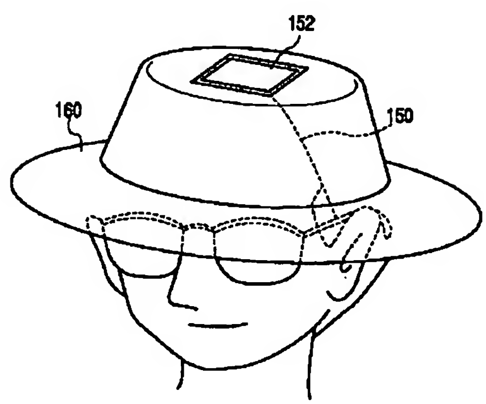
【図22】



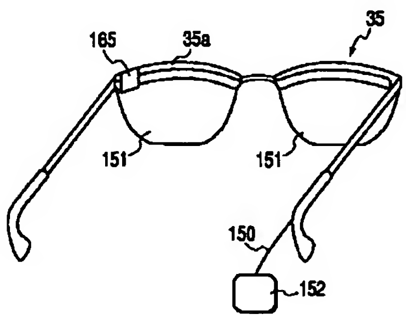
【図23】



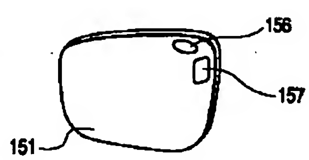
【図25】



【図27】



【図29】



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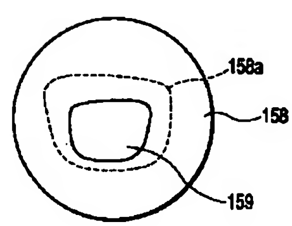

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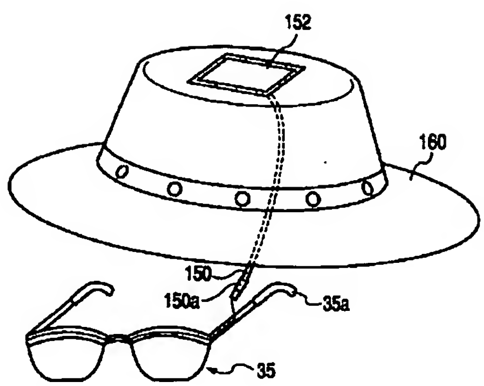

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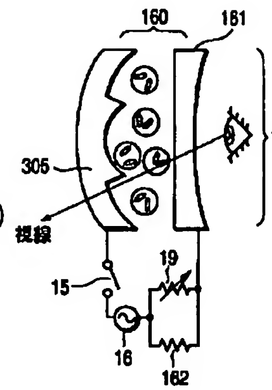

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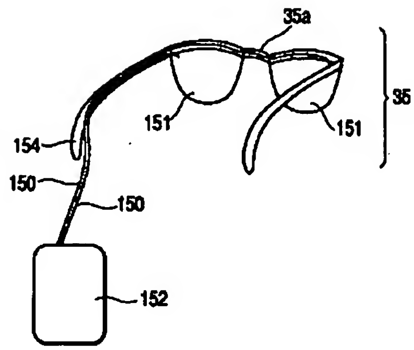

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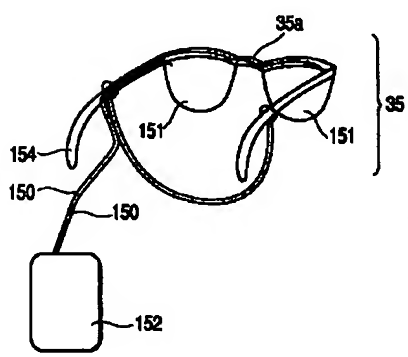
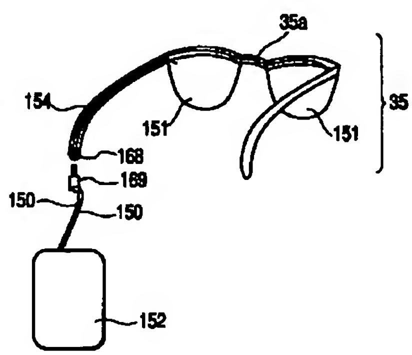


【図34】



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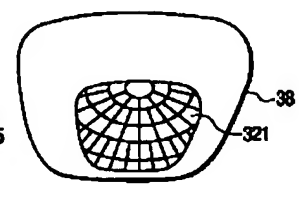

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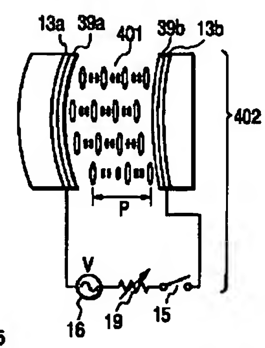
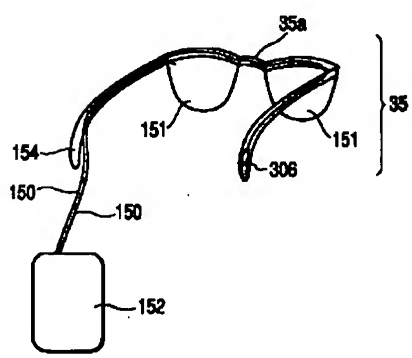
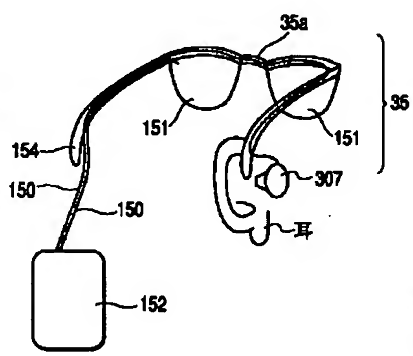


【図35】



【図36】



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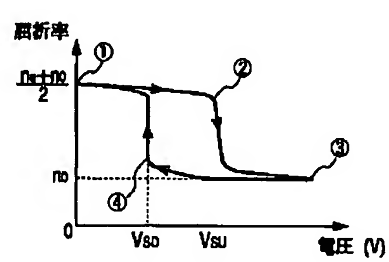

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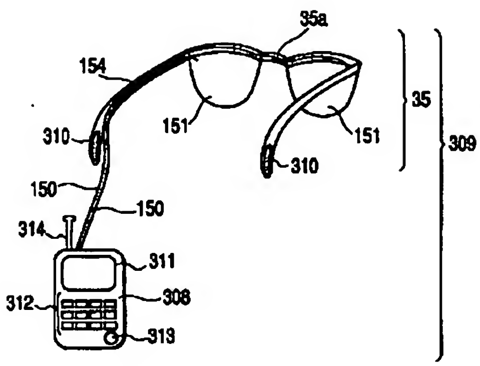

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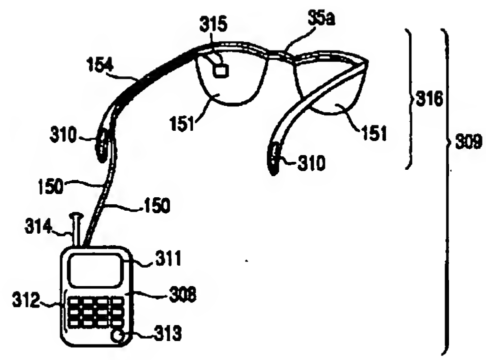

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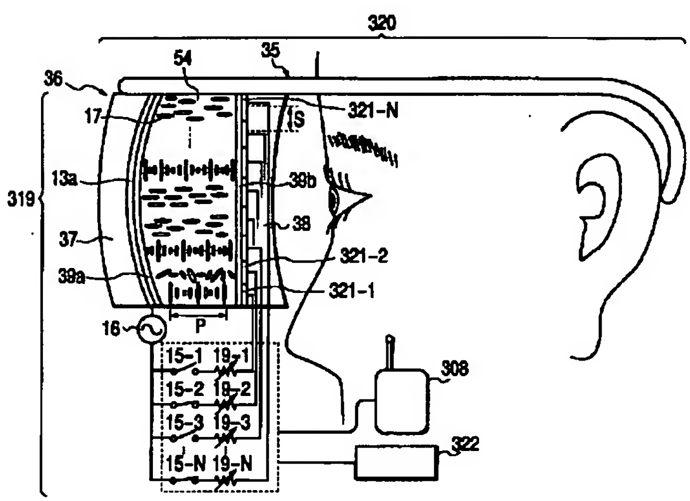

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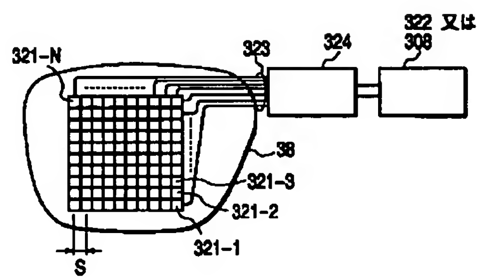

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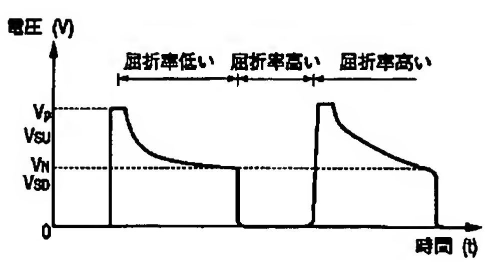

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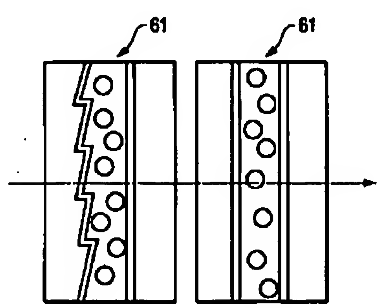

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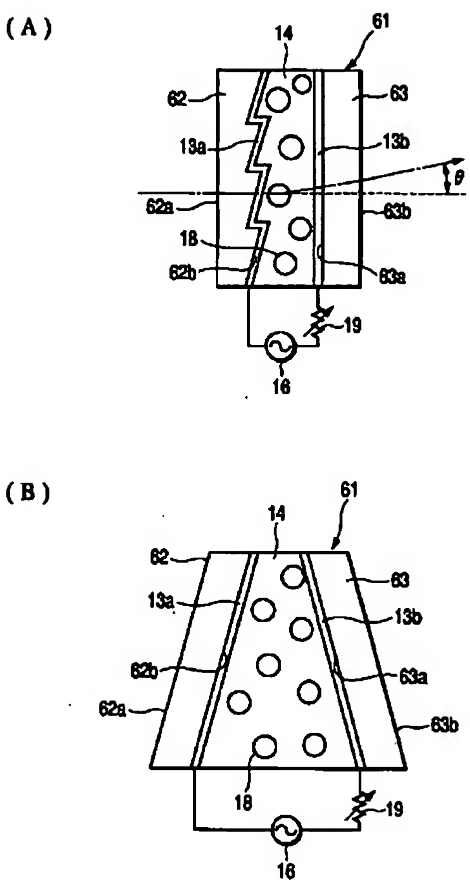
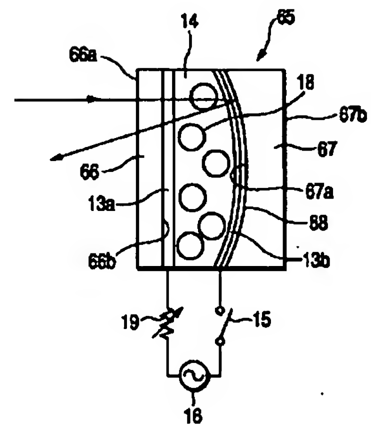

(A)
14
61
62
63
13a
13b
θ
62a
63b
18
62b
63a
19
16
(B)
14
61
62
63
13a
13b
62b
63a
62a
63b
18
19
16

【図47】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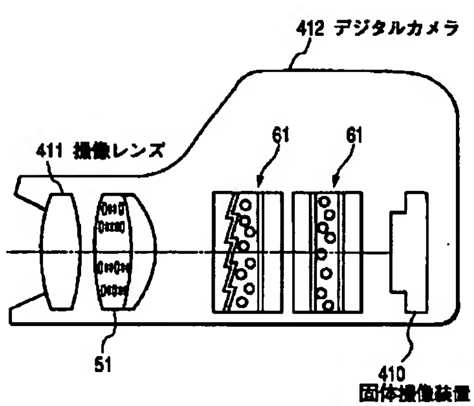
【図48】


412 デジタルカメラ
411 撮像レンズ
61
61
51
410
固体撮像装置